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# Evolution of the Small Magellanic Cloud

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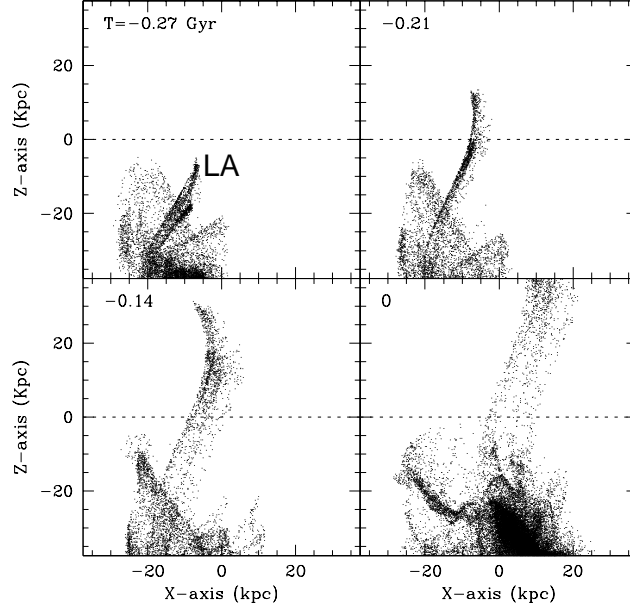
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## 1 Numerical simulations of the SMC evolution

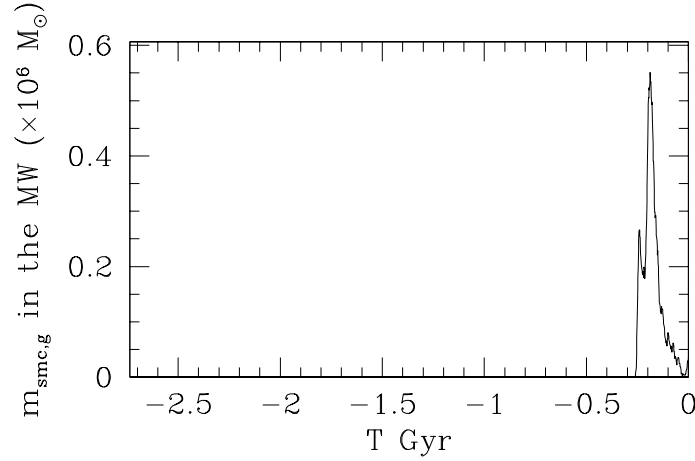
We investigate (1) the origin of the bifurcation of the Magellanic stream (MS), (2) the formation of distinctively metal-poor stellar populations in the Large Magellanic Cloud (LMC) due to sporadic gas transfer from the SMC, and (3) the collision between the leading arms (LAs) of the MS and the outer part of the Galactic HI disk based on numerical simulations of LMC-SMC-Galaxy interaction for the last 2.5 Gyr (e.g., Bekki & Chiba 2007, BC07). We adopt numerical methods and techniques of the simulations on the evolution of the MCs used in our previous papers (Bekki & Chiba 2005; B05): we first determine the most plausible and realistic orbits of the MCs by using “the backward integration scheme” (for orbital evolution of the MCs) by Murai & Fujimoto (1980) for the last 2.5 Gyr and then investigate the evolution of the MCs using GRAPE systems (Sugimoto et al.1990). The total masses of the LMC and the SMC are set to be  $2.0 \times 10^{10} M_{\odot}$  and  $3.0 \times 10^9 M_{\odot}$ , respectively, in all models. The SMC is represented by a fully self-consistent dynamical model whereas the LMC is represented by a point mass. We adopt the initial locations and velocities of the MCs with respect to the Galaxy that are similar to those adopted by BC07.

## 2 The Magellanic impact

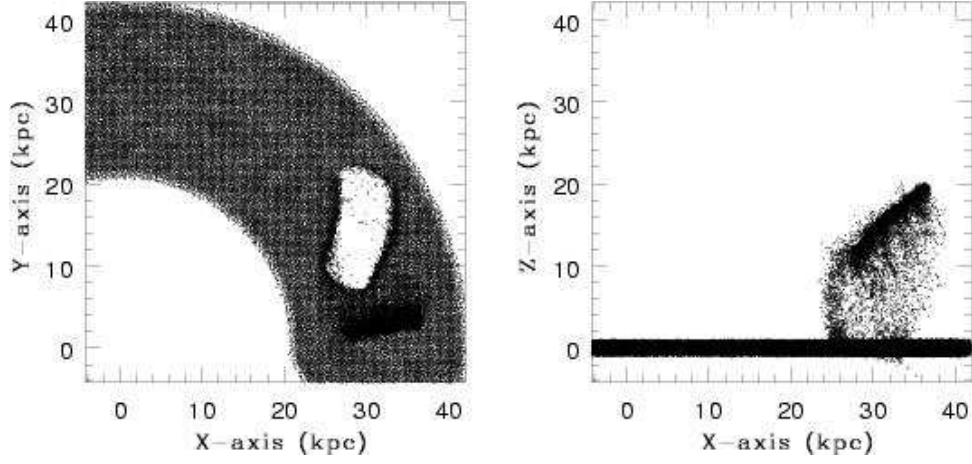
Although the bifurcation of the MS (i.e., two streams running parallel with each other in the MS) can be reproduced by the present tidal interaction model of the MS formation as well as by the previous ones (e.g., Connors et al. 2006), it has been unclear whether the tidal models can also reproduce the location of the kink of the LAs in the MS. We here propose that the observed location of the kink can be reproduced by the tidal model if the hydrodynamical interaction between the LAs and the outer part of the HI disk of the Galaxy is modeled in a reasonable and realistic way. Fig. 1 clearly shows



**Fig. 1.** Time evolution of the LAs of the MS for the last 0.27 Gyr. Only particles within 70 kpc from the center of the Galaxy are shown so that only the particles in the LAs can be more clearly seen. The time  $T = 0$  Gyr means the present whereas  $T = -0.27$  Gyr means 0.27 Gyr ago. The dotted line represents the disk plane of the Galaxy. Note that the LAs are composed of two streams passing through the Galactic disk about 0.2 Gyr ago.



**Fig. 2.** Time evolution of the total mass of the SMC's gas particles that are within the central 35 kpc of the Galaxy ( $m_{\text{SMC,g}}$ ). The locations of the peaks correspond to the epochs when the LAs pass through the Galactic disk.



**Fig. 3.** The final gaseous distributions projected onto the  $x$ - $y$  plane (left) and the  $x$ - $z$  one for the Galactic HI disk about 0.2 Gyr after the Magellanic impact. Note that as a result of the Magellanic impact, a giant HI hole can be created in the Galactic HI disk.

that the LAs, which are composed of two main streams, can pass through the outer part of the Galactic HI disk about 0.2 Gyr. This collision between the LAs and the HI disk is referred to as “the Magellanic impact” from now on for convenience. Fig. 2 shows that there are two peaks in the time evolution of the total mass ( $m_{\text{SMC,g}}$ ) of the SMC’s gas particles that were initially within the SMC and later stripped to be *temporarily* within the central 35 kpc of the Galaxy (note that particles within the central 35 kpc are counted or not at each time step, regardless of whether they are already counted prior to the time step). About 1% of the initial gas mass of the SMC (which corresponds to an order of  $10^7 M_{\odot}$ ) can pass through the HI disk of the Galaxy within the last 0.2 Gyr during the Magellanic impact.

Fig. 3 shows the results of our hydrodynamical simulations on the collision between the LA and the outer part of the HI disk of the Galaxy. The final snapshot of the simulation shown in Fig. 3 demonstrates that the Magellanic impact can push out some fraction of the HI gas of the Galaxy so that a giant (kpc-scale) HI hole can be created about 0.2 Gyr after the Magellanic impact. A chimney-like bridge connecting between the LA and the Galactic HI disk can be also created by the Magellanic impact. The HI velocity field close to the giant hole is significantly disturbed so that ongoing and future observations on kinematics of the Galactic HI disk can detect such a disturbance. Furthermore, the high-density ridge along the giant hole is one of the predicted properties that can be tested against observations. Owing to the hydrodynamical interaction between the Galactic HI disk and the LA, the orbit of the LA can be significantly changed after the Magellanic impact at

$l = 0$ . This means that the location of the simulated kink of the LA should be around  $l = 0$ , which is consistent with the observed location of the kink.

### 3 The Magellanic squall

One of another important results of the present simulations is that a significant amount of metal-poor gas is stripped from the SMC and fallen into the LMC during the LMC-SMC-Galaxy interaction over the last 2 Gyrs. We find that the LMC can temporarily replenish gas supplies through the sporadic accretion and infall of metal-poor gas from the SMC. We also find that about 0.7 % and 18 % of the SMC's gas can pass through the central region of the LMC about 1.3 Gyr ago and 0.2 Gyr ago, respectively. The possible mean metallicity of the replenished gas from the SMC to LMC is about  $[\text{Fe}/\text{H}] = -0.9$  to  $-1.0$  for the two interacting phases for an adopted steep initial metallicity gradient of the SMC's gas disk (BC07). We thus propose that this metal-poor gas can closely be associated with the origin of the observed LMC's young and intermediate-age stars and star clusters with distinctively low-metallicities with  $[\text{Fe}/\text{H}] < -0.6$  (e.g., Grocholski et al. 2006; Santos & Piatti 2004). We also suggest that if these gas from the SMC can collide with gas in the LMC to form new stars in the LMC, the metallicities of the stars can be significantly lower than those of stars formed from gas initially within the LMC. Accordingly this "Magellanic squall", which means gas-transfer from the SMC to the LMC, can be very important for the recent star formation history of the LMC: The evolution of the LMC is influenced not only by tidal effects of the SMC and the Galaxy but also by the mass-transfer from the SMC, if the MCs have been interacting with each other for the last 2 Gyrs.

### References

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